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Analysis of hub-and-spoke airport networks in Java Island, based on cargo volume and freight ratio

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Abstract

In recent years, air transport network in Soekarno-Hatta International Airport have become congested, leading to delays for business travelers, and freight shipments. One of the alternative solutions for this problem is to evaluate the hub-and-spoke airport networks. Hub-and-spoke airport networks enable carriers to supply transport services to many combinations of origin and destination zones at high frequencies and low costs. The disadvantage for the traveller is of course that they have to make a detour via the hub airport implying an extra stop. For many combinations of origin and destination zone, travellers can choose between more than one main carrier and airport. The aim of this paper is to analysis of hub-and-spoke airport networks in Java Island based on cargo volume and freight ratio. Based on freight ratio value, airport can be classified in four types: full passenger airport, freight interest airport, freight specialist airport, and mixed passenger and freight airport. This study shows that the flight route in Indonesia has not been fully developed in accordance with the concept of hubs-and-spokes. All of the six airports in Java Island (Soekarno-Hatta Airport Jakarta, Juanda Airport Surabaya, Adi Sucipto Airport Yogyakarta, Adi Sumarmo Airport Surakarta, Husein Sastranegara Airport Bandung, and Ahmad Yani Airport Semarang) for the domestic and international flight include in mixed passenger and freight airport type. Soekarno-Hatta Airport has the highest of freight ratio value, 8.128 for domestic flight and 24.738 for international flight. The percentage of cargo volume in Soekarno-Hatta Airport is 71.898% for domestic flight and 93.330% for international flight. The growth of hub-and-spoke airport networks has allowed medium and large-size airports that limited in passenger demand in the catchment area to become the primary hubs in their respective regions.

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Keywords: Hub-and-spoke; airport; cargo volume; freight ratio; Java Island.

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1. Introduction

The Government considers that logistics service still faces some problems, such as insufficient number of infrastructures, illegal payments, transportation costs that lead to high economic costs, and limited network and capacity of nationwide logistics service provider [1]. Given the major role that can be provided by air transport to the national logistics distribution system, the planning of a good air transport logistics distribution network is a must. At early stage, planning of an air transport logistics distribution network should consider to the existing conditions of airport infrastructure, warehousing, and logistics demand. Therefore, an analysis can be made to determine the best suited type of aircraft and location of logistics centers which provide the highest efficiency. However, the infrastructure should be considered as the object of planning, in which it plays role as an input to the development of air transport infrastructure.

One concept of logistics distribution that can be adopted is air transport in furtherance of other modes of transportation (marine and terrestrial). This concept is implemented especially for durable goods, in terms of both physically and value. However, a concept is also needed to be developed for distribution of perishable goods that require faster distribution. Especially for air transport, the concept of hub-spoke distribution can provide a high level of efficiency. However, all these things need to be more deeply studied to achieve effectiveness and efficiency in logistic distributions via air freight. Good freight distribution could eventually reduce the prices of capital and consumer goods so as to reduce the burden of public spending.

The aim of this paper is to analysis of hub-and-spoke airport networks in Java Island, Indonesia based on cargo volume and freight ratio. Based on freight ratio value, airport can be classified in four types: full passenger airport, freight interest airport, freight specialist airport, and mixed passenger and freight airport. Fives airport classifications based on Federal Aviation Administration (FAA) are large hub, medium hub, small hub, non-hub primary, and non-primary commercial service [2].

2. Literature

2.1. Hub and Spoke Network

Over the past twenty years since the enactment of the Airline Deregulation Act, domestic carriers have developed hub-and-spoke structures for their operations. These have been instrumental in helping to reduce the overall costs of air travel [3]. In the past ten years many scholars have probed how to avoid the usual delay and in-efficiency incurred in airside, landside, and airlines operations [4,5,6]. Airlines that want to introduce changes usually incur extra capital expenditures. Even though aforementioned researchers have presented solutions for solving airlines' scheduling problems, serious obstacles remain for airlines with respect to ground operations. Hub-spoke network pattern occurs when all flights are directed to the great central location and then the passengers change their flights to reach their final destination. Arrival of the aircraft at the hub from the spokes is well coordinated and after a while the passengers and goods go the other spoke and this pattern will be repeated several times a day [7].

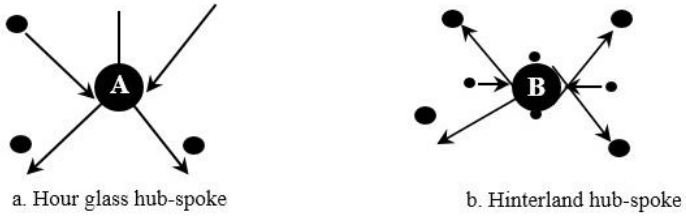

Fig. 1. Hub and spoke airport network [7].

The number of hub flight is based on the number of spoke and inter-connected city [8]. Classification of airport as a hub or spoke can be classified based on freight ratio (FR). Freight ratio is ratio between the number of cargo

(kg/passenger) and the number of passenger boarding in the airport. The classification of airport based on freight ratio is follows:

1. Full passenger airport is airport with freight ratio (FR) value is very low.
2. Freight interest airport is airport with freight ratio (FR) value between 30-100 kg per passenger.
3. Freight specialist airport is airport with freight ratio (FR) value is more than 100 kg per passenger.
4. Mixed passenger and freight airport is airport with freight ratio (FR) value is 30 kg per passenger and the number of passenger boarding in the airport is height.

This pattern consists of hubs that would serve as a center of economic and flight activity in a region and surrounding small towns spokes that will deal directly with it. Hub and spoke pattern has been known for a quite long time in the world of aviation. This pattern has been introduced and developed by the commuter groups in the United States since the early 1980s. The hub and spoke has been able to develop and organize the route, as well as promoting public interest and consumer; groups of trunks (hereinafter called themselves US Majors) and a group of locals (hereinafter called themselves US Nationals) also adopt it. These developments triggered by the enactment of Airline Deregulation Acts in 1978. Thus in this model, the flight routes consist of the central point (or hub) that serves multiple ends (spoke). Hub serves as a consolidation of passengers and goods that move from the various spokes and provide connecting flight next to various destinations, either to the next center or flights abroad. The airlines operate inter-hub flights several times a day, usually using aircraft with high capacity and range that accepts input of passenger from locations adjacent to the hub. The airlines are also arranged for a hub-and-spoke, using smaller aircraft, to provide a higher flight frequency, supporting the hub with a large number of spokes. The company is also building partnerships with regional airline operator or set up a subsidiary to build a network to remote area. Hub selection is based on the location and high enough market demand for a pair of "origin-destination" in favor of flight-operations. Accordingly, a detailed method of planning and route optimization is used to obtain an accurate basis for planning the transport system.

Table 1. Growth in power of a hub [8].

Number of spoke (n)	Number of connection C = n(n-1)/2	Number of city that connect with hub	Inter-connected city
2	1	2	3
6	15	6	21
10	45	10	55
50	1,225	50	1,275
100	4,950	100	5,050

The growth of hub-and-spoke networks has allowed medium and large size airports that limited in passenger demand in the catchment area to become the primary hubs in their respective regions [9]. The Airline Deregulation Act (ADA) of 1978 caused many changes in the industry. For the first time in 40 years, new airlines were permitted to enter the industry, and all airlines could choose the routes they would serve and the fares they would charge. Airlines were also free to exit the industry (go bankrupt), if they made poor choices in these matters [10]. The advantages of hub-and-spoke networks have been analyzed by several sets of researchers [11], discussed the effects of hub on airline costs and profitability. Basically, hub allows the airlines to fly routes more frequently with larger aircraft at higher load factors, thus reducing costs [12], looked at the effects of hub on passenger welfare, finding that, on average, passengers benefited from the switch to hub-and-spoke networks by receiving more frequent flights with lower fares and slightly shorter travel times. Large airports such as London Heathrow and Paris Charles de Gaulle have longer waiting times than the smaller airports Frankfurt and Schiphol even though one would expect shorter waiting times given the higher frequencies of service. The reason is that the flight co-ordination is less efficient and this is clearly reflected by the values of the flight co-ordination coefficient developed [13].

2.2. Point to Point Network Pattern

The high volume of flights through the hubs has resulted in congestion at specific hub airports in the 1980s and has created new opportunities for the airlines to provide services that are more practical i.e. back to point-to-point transport pattern. This approach was started by Southwest Airlines (SWA), which originated from offering services of short-distance flights (short haul), with no extra service (no frills) and cheap tickets (low-fare) connecting flights among

states in the USA. By avoiding these big cities routes, SWA create niche markets point-to-point which continues to grow. In the 1990s, Southwest was ranked 10th largest airline in the United States. Some examples of airlines that use these point-to-points are Southwest Airlines and The Southwest Effect. Southwest phenomenon started with Southwest Airlines offering direct routes to the route that is relatively less crowded, yet large enough to be flown by medium and regional planes with high frequencies and providing basic-service flight eliminating unnecessary luxuries brought forth new airlines with a similar business paradigm. This new airline offer not only business concepts of air transport services, but also a pattern of direct flight routes. This phenomenon has triggered more service providers cost point-to-point to the market, even some of the main flight operators such as Continental, Delta, and US Airways has made a subsidiary that offers point-to-point low and no extra luxuries. Southwest paradigm is to reduce the source of the high cost, generally they chose areas poorly served or secondary airports in urban areas, such as airports Love Field in Dallas. This business model is known as a low cost carrier (LCC) and was soon followed by other companies in the United States, Europe, and Asia [7].

2.3. Deregulation Hub and Spoke Network

From the pattern of the network or service flights on Fig. 2 Before Deregulation, seen its routes, with patterns point to point, where there are two airline (red and blue), which operates in 10 cities. With these restructuring and by using a hub and spoke pattern (Fig. 2 After Deregulation), the distribution of the second route each airline operating at a particular area and the main hub and make other destinations as spokes. The state will provide benefits to the airline, which the airline will be able to operate efficiently in the regulation of capacity, yield, and can increase market share and can provide a good profit margin. In addition it will also reduce the level of competition between the two airlines so that it would give market share which could lead to a monopoly, so it will provide a high entry barrier for new airline that will go on the stretcher.

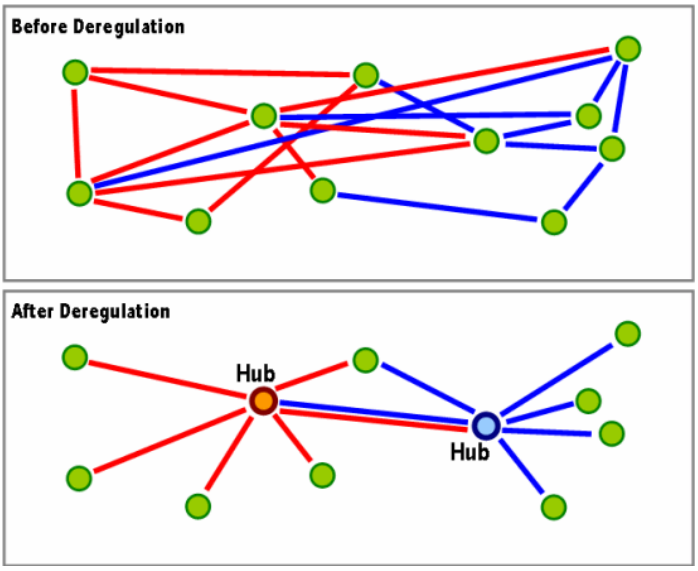

Fig. 2. Airport network before deregulation and after deregulation [11].

2.4. Federal Aviation Administration (FAA) Classification of Airport

The Federal Aviation Administration (FAA) has its own method for classifying whether an airport as a hub or non-hub. In Table 2 given the category of airports if used methods of grouping the FAA. In this method there are two criteria, the first is airport classifications (commercial service and non-primary) and the second is percentage of annual passenger boarding. There are five categories of airport i.e. large hub airport, medium hub airport, small hub airport,

non-hub primary airport, and non-primary commercial service airport [2].

Table 2. Classification of airport according to FAA [2].

Airport classifications		Hub type: Percentage of annual passenger boarding	Common name
Commercial service: Publicly owned airports that have at least 2,500 passenger boardings each calendar year and receive scheduled passenger service	Primary: Have more than 10,000 passenger boardings each year	Large: 1% or more	Large Hub
		Medium: at least 0.25%, but less than 1%	Medium Hub
		Small: at least 0.05%, but less than 0.25%	Small Hub
		Non-hub: More than 10,000, but less than 0.05%	Non-hub Primary
	Non-primary	Non-hub: at least 2,500 and no more than 10,000	Non-primary Commercial Service
Non-primary (Except Commercial Service)		Not Applicable	

3. Result and Discussion

Three criteria that has correlation with performance of cargo terminal according to users assessment include efficient and quick consumer response capabilities, delivery capability and fees, and sales representative service and reliability [14]. Costa propose Herfindahl-Hirschmann Index (HHI) method to measure the efficiency of airport networks that include number of airport effective (n_e) and number of hub airport (h) [15].

3.1. Hierarchy of Airport

Hierarchy of airport in Indonesia is classified into four levels i.e. primary hub, secondary hub, tertiary hub, and spoke. The hierarchy of six airports in Java Island, Indonesia are Husein Sastranegara International Airport Bandung is tertiary hub, Soekarno-Hatta International Airport Jakarta and Juanda International Airport Surabaya is primary hub, Ahmad Yani International Airport Semarang, Adi Sumarmo International Airport Surakarta, and Adi Sutjipto International Airport Yogyakarta are tertiary hub. Hierarchy of six airports in Java Island is shown in Table 3. Hierarchy of airports in Indonesia (34 airport) is shown in Fig. 3. From Fig. 3, there are 8 airports that include primary hub, 14 airports that include secondary hub, 11 airports that include tertiary hub, and 1 airport is a spoke.

Table 3. Six airports in Java Island.

No.	City, Province	Airports	Hierarchy of airport
1.	Bandung, West Java	Husein Sastranegara	Tertiary hub
2.	Tangerang, DKI Jakarta	Soekarno-Hatta	Primary hub
3.	Semarang, Central Java	Ahmad Yani	Secondary hub
4.	Solo, Central Java	Adi Sumarmo	Secondary hub
5.	Daerah Istimewa Yogyakarta	Adi Sutjipto	Secondary hub
6.	Surabaya, East Java	Juanda	Primary hub

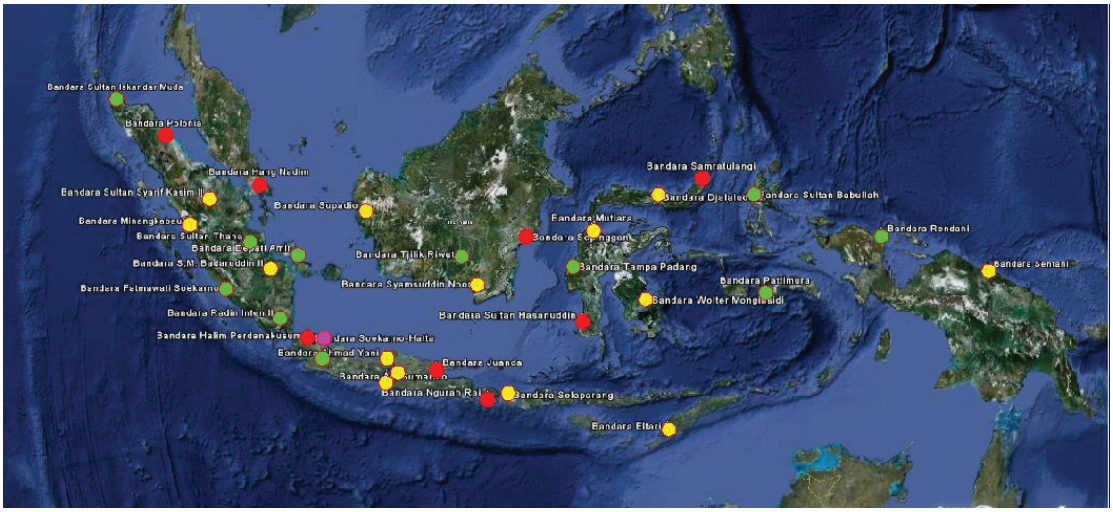

Fig. 3. Hierarchy of airport in Indonesia.

3.2. Freight Ratio Value for Domestic Flight

Freight ratio value for domestic flight from six airports in Java Island, Indonesia is shown in Table 4. The freight ratio value for domestic flight from six airports in Java Island between 1.362 to 8.128. Soekarno-Hatta International Airport has the highest of freight ratio value, 8.128 for domestic flight. Based on freight ratio value for domestic flight, all of the airport in Java Island include in mixed passenger and freight airport category.

Table 4. Freight ratio value for domestic flight from six airports in Java Island.

No.	Airport	Number of passengers boarding (people)	Number of cargo (kg)	Freight ratio	Category
1.	Husein Sastranegara	500,643	682,185	1.362	Mixed Passenger and Freight Airport
2.	Soekarno-Hatta	37,382,521	303,836,492	8.128	Mixed Passenger and Freight Airport
3.	Ahmad Yani	2,400,155	8,943,817	3.726	Mixed Passenger and Freight Airport
4.	Adi Sumarmo	1,009,150	3,005,592	2.978	Mixed Passenger and Freight Airport
5.	Adi Sutjipto	4,027,790	28,872,132	7.168	Mixed Passenger and Freight Airport
6.	Juanda	11,582,823	77,255,145	6.670	Mixed Passenger and Freight Airport

3.3. Freight Ratio Value for International Flight

Freight ratio value for international flight from six airports in Java Island, Indonesia is shown in Table 5. The freight ratio value for international flight from six airports in Java Island between 0.796 to 24.738. Soekarno-Hatta International Airport has the highest of freight ratio value, 24.738 for international flight. Based on freight ratio value for international flight, all of the airport in Java Island include in mixed passenger and freight airport category.

Table 5. Freight ratio value for international flight from six airports in Java Island.

No.	Airport	Number of passengers boarding (people)	Number of cargo (kg)	Freight ratio	Category
1.	Husein Sastranegara	437,202	356,261	0.815	Mixed Passenger and Freight Airport
2.	Soekarno-Hatta	10,864,684	268,773,723	24.738	Mixed Passenger and Freight Airport
3.	Ahmad Yani	32,256	435,971	13.516	Mixed Passenger and Freight Airport
4.	Adi Sumarmo	186,662	148,681	0.796	Mixed Passenger and Freight Airport
5.	Adi Sutjipto	209,195	378,086	1.807	Mixed Passenger and Freight Airport
6.	Juanda	1,409,415	17,890,398	12.693	Mixed Passenger and Freight Airport

3.4. FAA Classification

Airport classifications according to FAA method based on percentage of annual passenger boarding and cargo volume. The percentage value of cargo production for domestic flight and international flight from six airports in Java Island, Indonesia is shown in Table 6. The percentage of cargo production for domestic flight from six airports in Java Island is 0.161% to 71.898% and for international flight is 0.052% to 93.330%. Soekarno-Hatta International Airport has the highest of percentage of cargo production. The percentage of cargo volume (kg) in Soekarno-Hatta International Airport is 71.898% for domestic flight and 93.330% for international flight. Based on percentage of cargo production for domestic flight, 4 airport in large hub category (Soekarno-Hatta, Ahmad Yani, Adi Sutjipto, and Juanda), Husein Sastranegara in small hub category and Adi Sumarmo in medium hub category. For international flight, 4 airport in small hub category (Husein Sastranegara, Ahmad Yani, Adi Sumarmo, and Adi Sutjipto), 2 airport in large hub category (Soekarno-Hatta and Juanda).

The value of air transportation (Et) efficiency between 0-1. The value of Et is 1 if inter-connected every airport is *direct flight*. The value of air transportation (Et) efficiency with hub-spoke system is efficient if the Et value between 49-52% [16]. One of the methods to analysis the air transportation (Et) efficiency is Herfindahl-Hirschmann Index (HHI). Wiryanto and Haryanto use this method in 2012 to analysis the development of hub and spoke for logistic distribution of air transport in Papua Island, Indonesia [17]. Distribution of air transport logistic in Papua Island with hub and spoke system is not efficient, with the value of air transportation (Et) efficiency is 37.22%.

Table 6. Category of airport according to FAA Method.

No.	Airport	Domestic flight			International flight		
		Cargo production (kg)	Percentage	Classification according to FAA	Cargo production (kg)	Percentage	Classification according to FAA
1.	Husein Sastranegara	682,185	0.161%	Small Hub	356,261	0.124%	Small Hub
2.	Soekarno-Hatta	303,836,492	71.898%	Large Hub	268,773,723	93.330%	Large Hub
3.	Ahmad Yani	8,943,817	2.116%	Large Hub	435,971	0.151%	Small Hub
4.	Adi Sumarmo	3,005,592	0.711%	Medium Hub	148,681	0.052%	Small Hub
5.	Adi Sutjipto	28,872,132	6.832%	Large Hub	378,086	0.131%	Small Hub
6.	Juanda	77,255,145	18.281%	Large Hub	17,890,398	6.212%	Large Hub
	Total of cargo production (kg)	422,595,363		Total of cargo production (kg)	287,983,120		

4. Conclusions

The flight route in Indonesia has not been fully developed in accordance with the concept of hubs-and-spokes. All of the six airports in Java Island (Soekarno-Hatta International Airport Jakarta, Juanda International Airport Surabaya, Adi Sucipto International Airport Yogyakarta, Adi Sumarmo International Airport Surakarta, Husein Sastranegara

International Airport Bandung, and Ahmad Yani International Airport Semarang) for the domestic and international flight include in mixed passenger and freight airport type. Soekarno-Hatta International Airport has the highest of freight ratio value, 8.128 for domestic and 24.738 for international flight. The percentage of cargo volume in Soekarno-Hatta International Airport is 71.898% for domestic and 93.330% for international flight. The growth of hub-and-spoke airport networks has allowed medium and large-size airports that limited in passenger demand in the catchment area to become the primary hubs in their respective regions.

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